EDF No.: EDF-4271 EDF Rev. No.: Rev. 0 Project File No.: _____

1. Title: Quantification of Three Debris Objects from the South Basin of CPP-603 Using the Underwater Gamma Spectrometer system (TUGS)

2. Index Codes:
Building/Type CPP-603 SSC ID _____ Site Area INTEC

3. NPH Performance Category: _____ or x N/A

4. EDF Safety Category: _____ or x N/A SCC Safety Category: _____ or x N/A

5. Summary:
Three small, high-activity debris objects (SHADO) designated SHADO1, SHADO2 and SHADO3 were retrieved from the South Basin of CPP-603 and assayed for waste disposal characterization. Analysis indicates **13.56±2.72 Ci** of Cs-137 activity in **SHADO1**, and **4.69±1.24 Ci** and **385.25±80.48 Ci** of Co-60 activity in **SHADO2** and **SHADO3** respectively. Because of the presence of the fission product Cesium-137, SHADO1 may contain Uranium, whereas SHADO2 and SHADO3 may be irradiated fuel components but are not Uranium-bearing fuel.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

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Doc. Control		Kathryn Jenson	Kathryn Jenson	12.9.03
7. Distribution: (Name and Mail Stop)		See attached.		

8. Does document contain sensitive unclassified information? ☐ Yes x No
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9. Can document be externally distributed? x Yes ☐ No

10. Uniform File Code: 7653.P.6.3.4 Disposition Authority: SS5
Record Retention Period: Lifetime

11. For QA Records Classification Only: x Lifetime ☐ Nonpermanent ☐ Permanent
Item and activity to which the QA Record apply:

12. NRC related? ☐ Yes x No

13. Registered Professional Engineer's Stamp (if required)

Quantification of Three Debris Objects from the South Basin of CPP-603 Using the Underwater Gamma Spectrometer system (TUGS)

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1 INTRODUCTION

The CPP-603 basins consist of 3 main basins and several ancillary and connecting basins, pools, pits and channels in which spent fuel elements were stored or handled. The basins in CPP-603 were emptied of their inventories of spent fuel elements by 2001. The above areas were scanned and characterized for any remaining debris[1]. Several of the most radiologically active debris elements located during the basin scanning were retrieved from the South Basin for further, more detailed characterization. The characterization included those noted as small, high activity debris objects (SHADO) and previously measured generic fuel objects (GFO). Multiple SHADO items were visually identified, and the most active item (as measured using an underwater ion chamber) of each type was used as a reference for total curie content. The total item count is noted in Section 3.1. This characterization was performed using The Underwater Gamma Spectrometer (TUGS), shown in Figure 1.

2 SHADO OBJECTS

The three most radiologically active debris pieces located during basin scanning were retrieved from the South Basin. The objects are designated SHADO1, SHADO2, and SHADO3 and are listed in Table 1.

debris piece	description	dimensions	TUGS spectral filename
SHADO1	Al Plate NBS/MTR	12" x 2.5" x .0625" thk	082703_SHADO1_15ksec.cnf
SHADO2	EBR Upper Adapter hex rod	15" x 1.75" dia.	082703_SHADO2_1870sec.cnf
SHADO3	EBR-II Lower Adapter hex rod	44" x 1.75" dia.	082703_SHADO3_1829sec.cnf

Table 1 Debris Objects SHADO1, SHADO2, SHADO3

2.1 Debris Objects SHADO1, SHADO2, SHADO3[Error! Bookmark not defined.]

The debris object designated SHADO1 is an Aluminum Plate measuring 12" x 2.5" x .0625". This size estimate is based on video inspection of the object underwater. The plate is folded over approximately 4" along the length so that it is effectively 8" in length. The SHADO1 debris object was placed within a CAN-SF-52 (5" dia) to facilitate handling as indicated in Figure 2.

Based on initial underwater inspection, SHADO1 was initially postulated to be a plate from the National Bureau of Standards (NBS) MTR-type fuel. This identification was based on the physical size and apparent configuration of the object. According to records, the NBS fuel was received at CPP-603 in 1982 and processed through dissolution and separations in 1985[2]. The fuel elements were 17-plate assemblies, approximately 12.656 inches in length, 2.625 inches wide and 0.050 inches thick (SHADO1 is approximately 12"x2.5"x.065"). The complete assemblies contained 129 g of Uranium-235 at beginning of life (BOL) at 93.5% enrichment and 6.4 wt % Uranium. An individual plate would have had 7.59 g U-235 at BOL. The fuel was reportedly operated to a 57% burnup level. That burnup would lead to an end of life (EOL) Uranium-235 content of 3.235 g in a plate. In a high-enriched fuel, since Cesium-137 is a fission product, there is a direct relationship between the amount of Cesium-137 and the amount of fissile material consumed. From the J.W. Sterbentz

parametric study of fuel burnups[3], the Cesium-137 fission product content of a fuel component that had experienced consumption of 4 g of U-235 would be approximately 7.4 curies after a 20-year storage period. A complete burnup of the fissile material in the plate would result in production of 12.9 Curies Cesium-137.

The debris object SHADO2 is an Experimental Breeder Reactor (EBR) upper adaptor hex rod nominally 22" in length and 1.75" diameter. The top 7" of SHADO2 was removed, resulting in a 15" length. For these estimates we will approximate the hexagonal rod shape as a cylindrical rod. This is done because the component has an exterior shell that is hexagonal sheet metal, but a center core that is a solid cylindrical rod. This item was handled bare, and positioned in the TUGS guide rings at a nominal 15° angle.

The debris object SHADO3 is an EBR-II lower adaptor hex rod nominally 44" in length and 1.75" diameter.

SHADO2 and SHADO3 were handled bare, positioned in the TUGS guide rings at a nominal 15° angle.

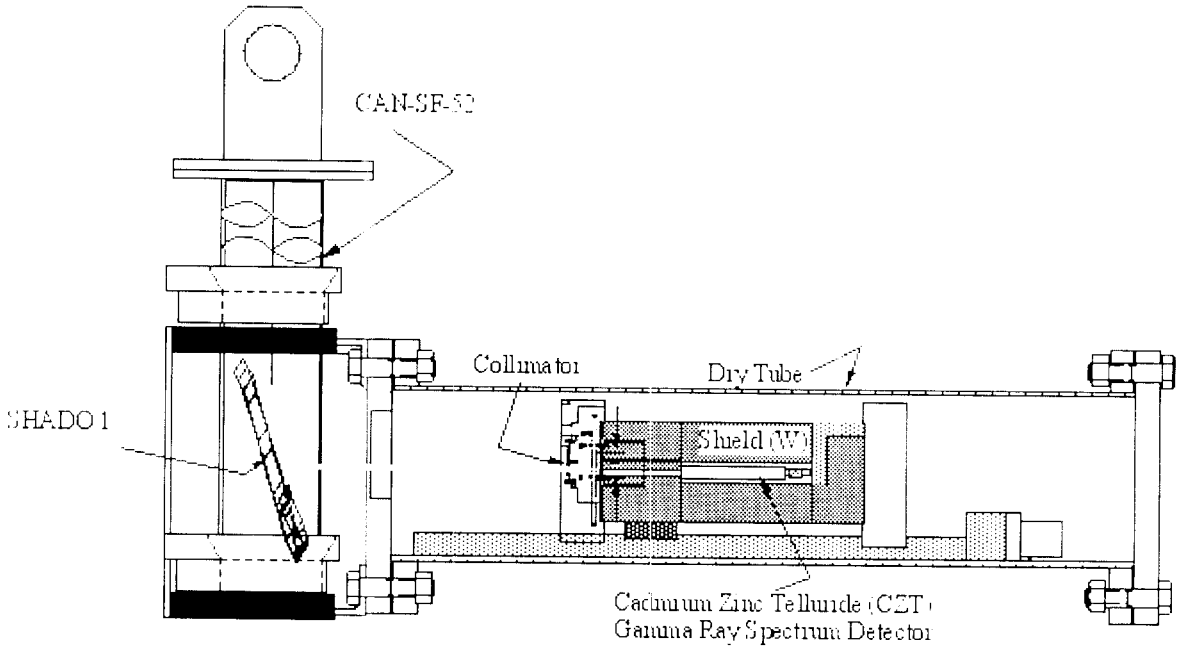

Figure 1 TUGS Detector Package

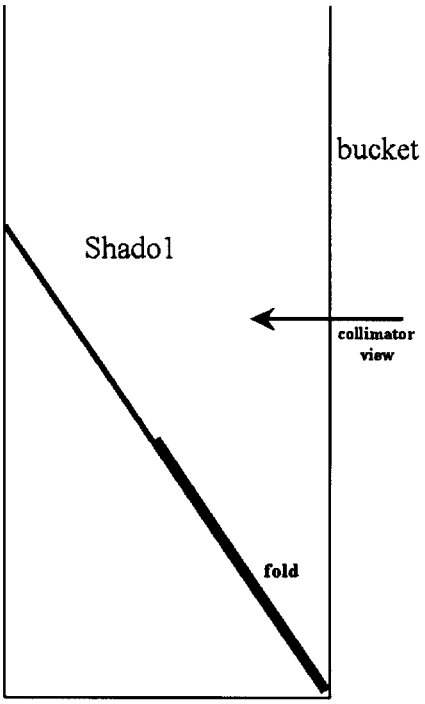

Figure 2 Debris object SHADO1 placed within the TUGS bucket

2.2 TUGS Gamma Spectroscopy

The objects were assayed using the TUGS system (Figure 1). The resulting gamma spectra are shown in Figure 3 to Figure 5. Only Cesium-137 was identified in SHADO1. Only Cobalt-60 was identified in SHADO2 and SHADO3. No other gamma-emitting isotopes were detected. No Uranium x-rays were observed in any of the three assayed debris object gamma-ray spectra. Tungsten x-rays, resulting from gamma interactions in the TUGS Tungsten collimator assembly were detected at 59 keV in the spectra of all three SHADO debris objects.

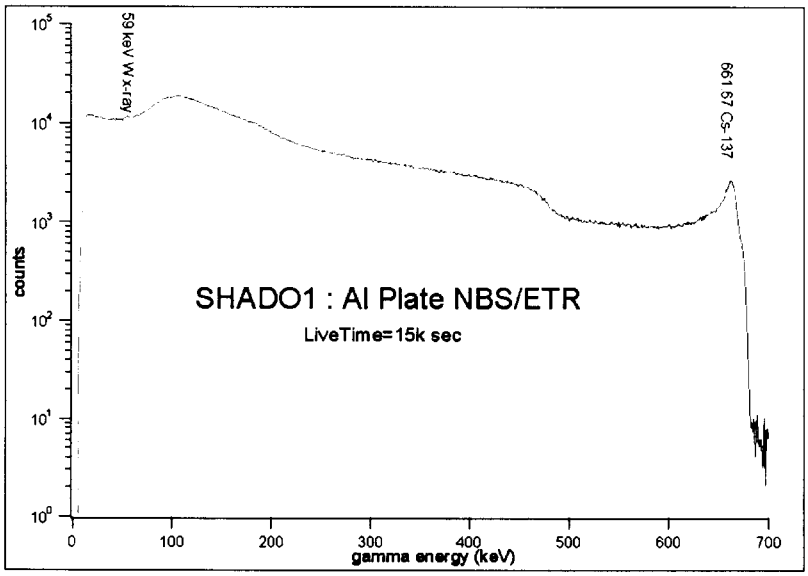

Figure 3 Gamma spectrum 082703_SHADO1_15ksec.cnf of SHADO1. Note the absence of Uranium x-rays.

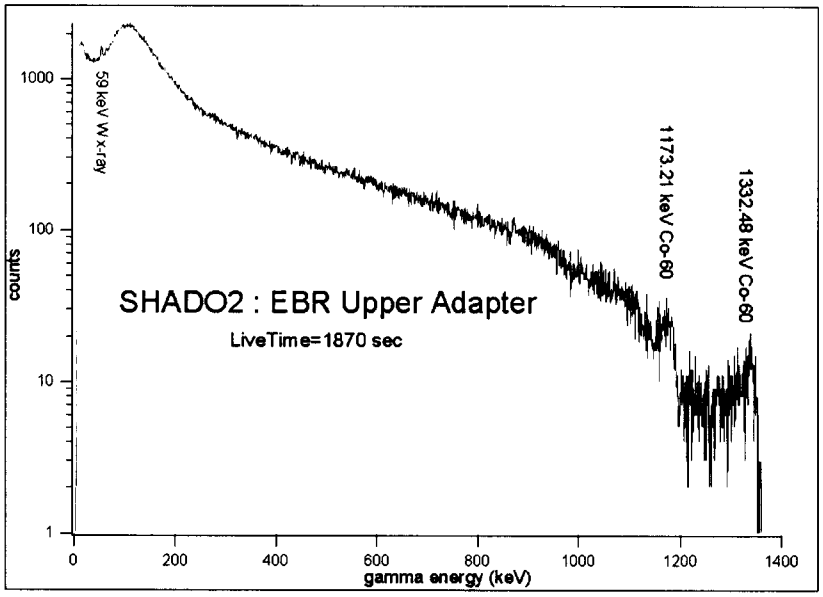

Figure 4 Gamma spectrum 082703_SHADO2_1870sec.cnf of SHADO2.

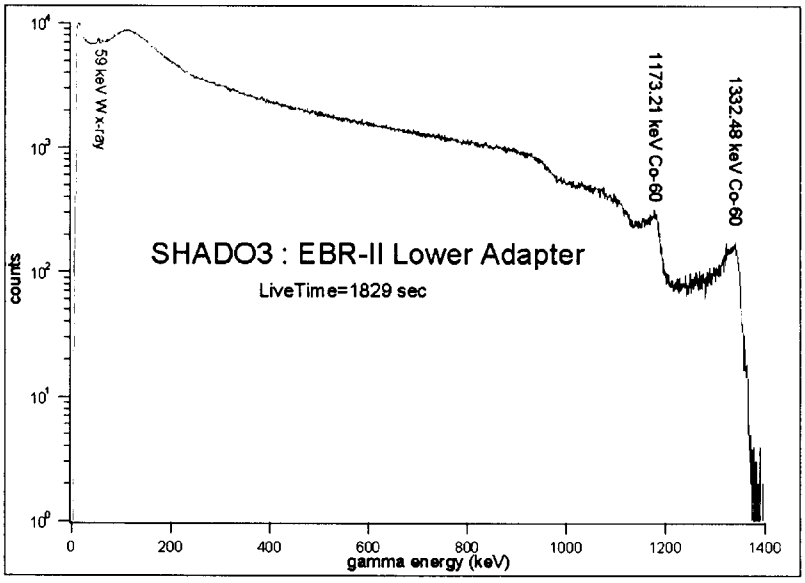

Figure 5 Gamma spectrum 082703_SHADO3_1829sec.cnf of SHADO3.

Cs-137 activity was identified in debris object SHADO1. Co-60 activity was identified in both SHADO2 and SHADO3, indicating the presence of activated metals, i.e.-stainless steel.

2.3 TUGS Gamma Spectra Analysis

Radiological activity within the debris objects was quantified by analyzing the above spectra within Genie-2000. The resulting fit to the 661.67 keV Cs-137 photopeak in SHADO1 is shown in Figure 6. The background component is shown under the photopeak in Figure 6.

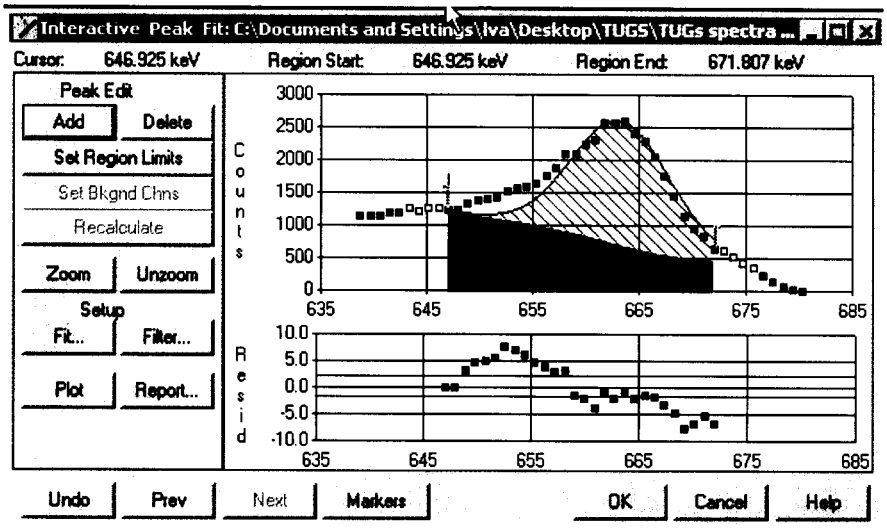

Figure 6 Genie-2000 peak fitting display, SHADO1 6761.67 keV Cs-137 photopeak

The SHADO2 and SHADO3 debris objects were analyzed similarly. The 1173.2 keV and 1332.5 keV Co-60 photopeaks were the only peaks of any relevance analyzed.

2.4 Activity Calculations

The radiological activity for this photopeak was calculated as

$$\text{Activity } (\mu\text{Ci}) = \frac{\text{PeakArea (cnts)}}{\text{Live Time (sec)}} \frac{\text{conversion\_to\_}\mu\text{to}}{\text{Efficiency(photopeak)}} \frac{1}{\text{branch(photopeak)}}$$

where Efficiency(photopeak) was measured and calculated as presented in EDF-2590[4].

The resultant activity is that measured through a 3mm diameter Tungsten collimator. The measured activity is therefore that measured only within the field of view (FOV) of the collimator. It is assumed that the activity measured within the FOV of the collimator is representative of the activity within the remaining unmeasured portion of the object outside the collimator field of view. The activity of the entire object may then be calculated by scaling its value by the ratio of the cross sectional area of the object to the collimator field of view area.

The measured activity is also corrected for the angle at which it rests relative to the collimator direction as in Figure 2. The results of the TUGS measurements, including corrections, for SHADO1, SHADO2 and

SHADO3 are shown in Table 2. The efficiency and associated error values are as in EDF-2590[4]. The correction factor includes field of view effects and angle effects discussed above. Intermediate errors are propagated through to obtain the final error values.

debris piece	description	filename	livetime (sec)	deadtime (%)	peak Energy (keV)	Nuclide	peak Area (cnts)	cps	area err (%)	Efficiency (c/gamma)	error (%)	branch	Activity (Bq)	Activity (Ci)	corr. factor	corr. Activity (Ci)	err (%)
SHADO1	Al Plate NBS/MTR	082703_SHADO1_15ksec	15228.78	0.46	661.67	^{137}Cs	23736	1.55	1.56	2.184E-09	20.0	0.8512	8.346E+08	2.26E-02	601	13.56	20.06
					59.3182	W ka	1616.09	0.11	28.4								
SHADO2	EBR Upper Adapter	082703_SHADO2_1870sec	1870.39	1.11	1173.21	^{60}Co	233.09	0.12	17.1	4.152E-10	20.0	1	2.968E+08	8.02E-03	584	4.69	26.37
					1332.48	^{60}Co	176.43	0.09	11.1	3.243E-10	20.0	1	2.876E+08	7.77E-03	584	4.55	22.87
					59.3182	W ka	819.79	0.43	20.3								
SHADO3	EBR-II Lower Adapter	082703_SHADO3_1829sec	1829.15	6.20	1173.21	^{60}Co	5209.68	2.67	4.27	4.152E-10	20.0	1	6.435E+09	1.74E-01	1757	305.59	20.45
					1332.48	^{60}Co	5129.71	2.63	6.03	3.243E-10	20.0	1	8.112E+09	2.19E-01	1757	385.25	20.89
					59.3182	W ka	1808.1	0.93	23.6								

Table 2 Measurement and Analysis Results: SHADO1, SHADO2, SHADO3

3 Conclusions

SHADO2 and SHADO3 were found to have significant activity only in 1173 keV and 1333 keV Co-60 gamma-ray peaks. This activity is due to the activation of metals in the debris objects, primarily stainless steel. Tungsten x-rays were also observed, originating in the Tungsten shield/collimator assembly in the TUGS apparatus (Figure 1). It is clear from visual examination that SHADO2 and 3 are components from disassembled EBR-II fuel. Visual examination underwater further confirms the lack of fuel pins in the adaptor components and hexagonal tubes.

SHADO1 was also found to have Tungsten x-rays due to the TUGS collimator/shield assembly. SHADO1 was found to have significant activity in only the 662 keV Cs-137 gamma-ray peak.

An activity level of 12.9 Curies Cs-137 was postulated in Section 2.1 assuming SHADO1 is a NBS MTR-type fuel plate. This value is consistent with the 13.6 Curie value calculated for SHADO1.

The lack of measured gamma emitting fission products other than Cesium-137 raises a question as to whether SHADO1 is a fuel object. No cesium sources having consistent dimensions or activity have been reported. Assuming it is an NBS-MTR plate with 57% burnup, SHADO1 may be presumed to have Uranium content of approximately 3 g. Other fission product content can be assigned according to the values in the Sterbentz parametric study. Among gamma emitters, Cesium-134 content may be expected to be 1.2 millicuries; Europium-152, 9.3 mCi; Europium-154, 16 mCi[3]. Since these isotopes are present in quantities more than three orders of magnitude lower than the cesium-137 value, they are undetectable in this material and detector configuration.

Therefore, SHADO1 is probably Uranium-bearing whereas SHADO2 and SHADO3 are irradiated fuel components but are not Uranium-bearing.

3.1 Summary

The measurements detailed in this document, as well as previous characterizations to be discussed in this section were performed on the most radiologically active objects[1] located in the CPP-603 fuel storage basins. The result is that a conservative estimate (upper estimate) of radiologically active debris objects located within the storage basins is obtained and appropriate disposal can be arranged for any further, and presumably less radiologically active, debris objects retrieved from the basins.

The highly active debris objects identified in the CPP-603 basins are as follows:

SHADO1:1 ea. Aluminum plate, nominal dimensions 12" x 2.5" x 0.0625"
Gamma ray spectrometry shows:
13.56 Ci +- 20.1% As measured in the Cs-137 661 keV peak

SHADO2. 3 ea. Stainless steel solid rod components, nominal dimensions 44" long x 1.75" diameter
Gamma ray spectrometry shows:
305.59 Ci +- 20.45% As measured in the Co-60 1173 keV peak
385.25 Ci +- 20.89% As measured in the Co-60 1332 keV peak

SHADO3. 3 ea. Stainless steel solid rod component, nominal dimensions 22" long x 1.75" diameter
Gamma ray spectrometry shows:
4.69 Ci +- 26.37% As measured in the Co-60 1173 keV peak
4.55 Ci +- 22.87% As measured in the Co-60 1332 keV peak

SHADO4. 3 ea. Stainless Steel tubing nominal dimensions 22" long x 1.75" diameter, wall thickness 0.120"
Estimated activity based on mass comparison of 5 lb per foot for tubing and 9 lb per foot for solid rod, 2.57 Ci as estimated from average of Co-60 peaks of item 3.

Generic Fuel Objects GFO2, 3, 4 &5. 4 ea. Stainless Steel clips, nominal dimensions 0.5" x 6" x 0.25"
Gamma ray spectrometry measured value:
Maximum 0.975 Ci Co-60 +/- 27%
(Measured in 2001 by J. K. Hartwell, using TUGS[5].
Previously noted as GFO 2, 3, 4, and 5.)

The sum total, including uncertainty, amounts to nominally 16 Ci Cs-137 and 1280 Ci of Co-60.
These five set of objects are detailed in Table 3.

Table 3 Summary of High Radiologically Active Debris Objects Characterized

Item	Number	Activity (Ci)	Isotope	Average Activity (Ci)	Uncertainty (%)	Subtotal (Ci)
1	1	13.56	Cs-137	13.56	20.1	16.29
2	3	305.59	Co-60	345.42	20.9	1252.84
		385.25				
3	3	4.69	Co-60	4.62	26.4	17.52
		4.55				
4	3	2.57	Co-60	2.57	26.4	7.71
5	4	0.975	Co-60	0.975	26.	4.91
				Total Curies		1299.27
				Total Co-60		1282.98
				Total Cs-137		16.29

This quantity of activity represents the high activity object component of the total basin radiological source term, the other two components being that measured in the basin scanning process, and that analyzed from basin sludge and water, reported in EDFs 3535 and 4235, respectively.

4 REFERENCES

[1] EDF-3535, *CPP-603 Basins - Fissile Material in Particulate Form based on ^{137}Cs to ^{235}U Ratio.*, L. A. Van Ausdeln
[2] Attachment to G.F. Offutt letter Off-25-82
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[4] EDF-2590, *The Underwater Gamma Spectrometer (TUGS) Calibration and Integral Test Report*, J. K. Hartwell
[5] *Assay of Three Generic Fuel Objects (GFOs) at INTEC 603 Using The Underwater Gamma Spectrometer (TUGS): Result Report* ,J. K. Hartwell, Interoffice Memorandum, May 2001.